An Annotated and Federated Digital Library of Marine Animal Sounds

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LONG-TERM GOALS

The Macaulay Library is the world's largest archive of animal sounds and has been selected by the Office of Naval Research as a major repository for the deposition, digital archival, review, and retrieval of the many recordings of marine animals made over the last half-century. Archived marine recordings pose challenging retrieval problems given the typically long intervals of silence between animal sounds and the multiplicity of species detectable in any given recording. One goal of this project is to design software that will permit remote experts to annotate the content of long recordings archived at the Macaulay Library through their web browsers. Annotations will permit subsequent searches of the archive database to retrieve not only suitable recordings, but also those parts of a recording meeting the search criteria. The project also seeks to define and extract a set of acoustic features from all archived marine recordings that can be used in subsequent search and retrieval tasks. Both capabilities will be unique to this sound collection, and will greatly enhance the accessibility and the utility of the archive to scientists, students, educators, military personnel, and the media.

OBJECTIVES

To achieve the annotation goals, the project must provide a) a browser-based software tool for visualizing and playing back digitized sounds stored in the archive; b) mouse-driven tools for identifying specific segments within the visual image of the sound; c) pull down menus that allow the annotator to assign standardized metadata terms for annotation as well as entry of custom notes to specific segments within recordings; d) suitable metadata structures for storage of the annotations and the relevant segment delimitation points and linkages to other relevant metadata fields; e) search engines that support the invocation of annotation terms during searches along with other standard criteria; and f) retrieval tools that identify relevant parts within archived recordings, mount the

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recording, create a visual image, and move to the relevant annotated segments. All of these tools must allow multiple annotators to add information to the same recording, and search engines that permit either all-annotator or specific-annotator searches. To our knowledge, no archive currently provides suitable tools to meet these requirements. They thus must be created from scratch by this project.

To achieve the extracted feature goal, we need to: a) obtain a consensus from the marine acoustics community on which common measures would best facilitate their use of the sound archive; b) create the relevant algorithms and test them; c) implement the algorithms so that they can be applied directly to annotated segments in the archive; and d) provide suitable metadata structures to store the extracted feature data and link them to the other fields pertinent to any recording. At some later date, automatic batch signal detectors and segment delimiters will be developed that will allow extraction on all recordings, whether yet annotated or not. However, that step is not part of the current project.

APPROACH AND WORK PLAN

The annotation and feature extraction software tools are both complex tasks because they require seamless integration of visualization, user input, database design and manipulation, search engine, and web usability components. The tasks have been broken into discrete modules and specifications written for each module, including definition of deliverables and due dates. The Macaulay Library metadata model required a major reconstruction and transfer into an Oracle relational environment. Critical to this effort was the incorporation of existing or development of new metadata standards for habitat type, taxonomy resolution, and classification of associated behaviors. All software for search, retrieval, and manipulation is being written in Java to ensure cross-platform compatibility. The visualization tool, (creating spectrograms and waveforms of any archived sound), posed unique challenges because it had to work in a browser environment, handle both audio and video archived files, guarantee proper digital rights protection, be instantaneous in operation, allow for segment selection by remote users, and meet the high standards for spectrogram resolution demanded by the marine bioacoustics community. Our solution has been to build this tool using Apple Quicktime, a utility available on all user platforms for free and providing all the necessary requirements. The feature extraction tools require input from the marine bioacoustics community at all stages. This is being handled by a) including critical members of that community as partners in the project, b) holding workshops where optimal features can be discussed, and c) recruiting testing and critique input from a variety of marine bioacoustics labs throughout the United States as algorithms are implemented.

Senior programmer William Sandner oversees the project, delegates JAVA tasks, and works himself on critical parts of the module. Rafe Rosen and Gui Iacino each work on programming other modules in the project. A number of Cornell undergraduates in Computer Science have also contributed to programming tasks under Mr. Sandner's direction. Erica Olsen is our web interface designer and usability tester. Tim Levatich handles all the metadata modeling, implementation, and database management. Roger Slothower is developing the mapping tools. The Quicktime visualization tool was developed by Totally Hip Technologies, Inc., a Vancouver, British Columbia company that specializes in Quicktime extensions. The Bioacoustics Research Program at the Cornell Lab of Ornithology, including partners Dr. Chris Clark and Kurt Fristrup, are providing critical input on the optimal design of the visualization tools and the feature extraction module. Partner Dr. David Mellinger has also provided critical input on feature selection, and will implement the initial algorithms in a Matlab environment so that they can be distributed, examined, and critiqued by participating marine bioacoustics laboratories around the country. Dr. Sue Moore, another partner, will be providing critical assistance in recruiting suitable participant labs and in feature selection.

As noted below, the search, playback, and visualization tools are completed and available for beta testing on the Macaulay Library website. The digitized marine animal sound collection is also now available for browsing. The goal for the remainder of the year is to complete the annotator interface, test it with volunteer annotators, and refine its usability. The feature extraction algorithms have been selected and written into Matlab. The goal this year is to obtain testing of them in various research labs, refine them, and then implement them so that all annotated segments of recorded sounds are concurrently feature extracted in the background. Search tools using the stored features will also be completed this coming year.

WORK COMPLETED

The revision of the database and importation of legacy data into the new Oracle environment was completed in the first year of the award. This was followed in April 2005 with the initial release of the search, search results, mapping and sound visualization tools. The latter have been significantly refined in the ensuing 8 months. A typical search results page now appears as follows:

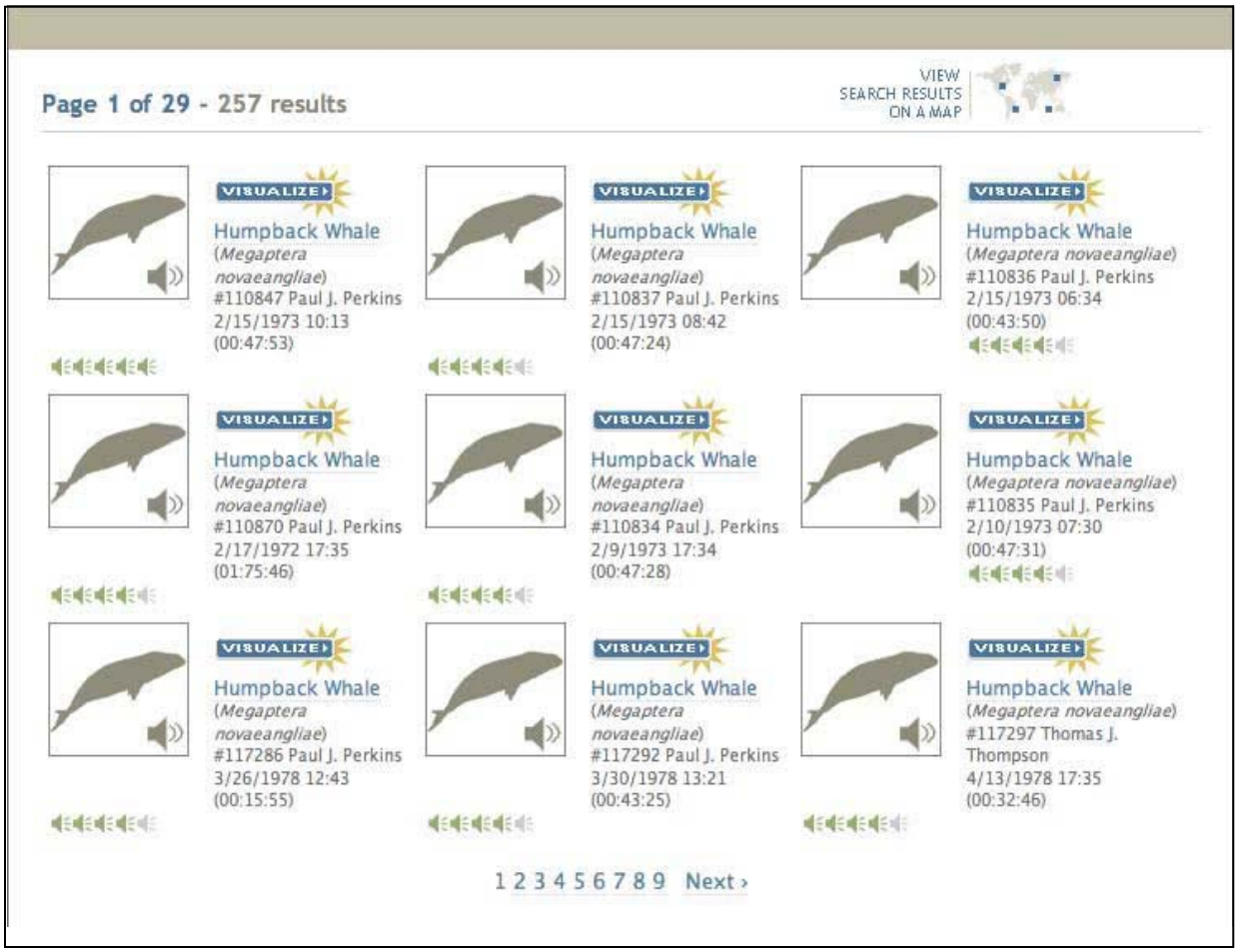

Figure 1: Sample results page after search for "humpback whale"

Once a search is completed, the user can then use the now widely familiar Google map tools to display the locations of the recordings found by the search. Clicking on any of the site tags creates a balloon

providing some information about that site's recordings and allowing the user to play that sound and/or obtain more information about the recording:

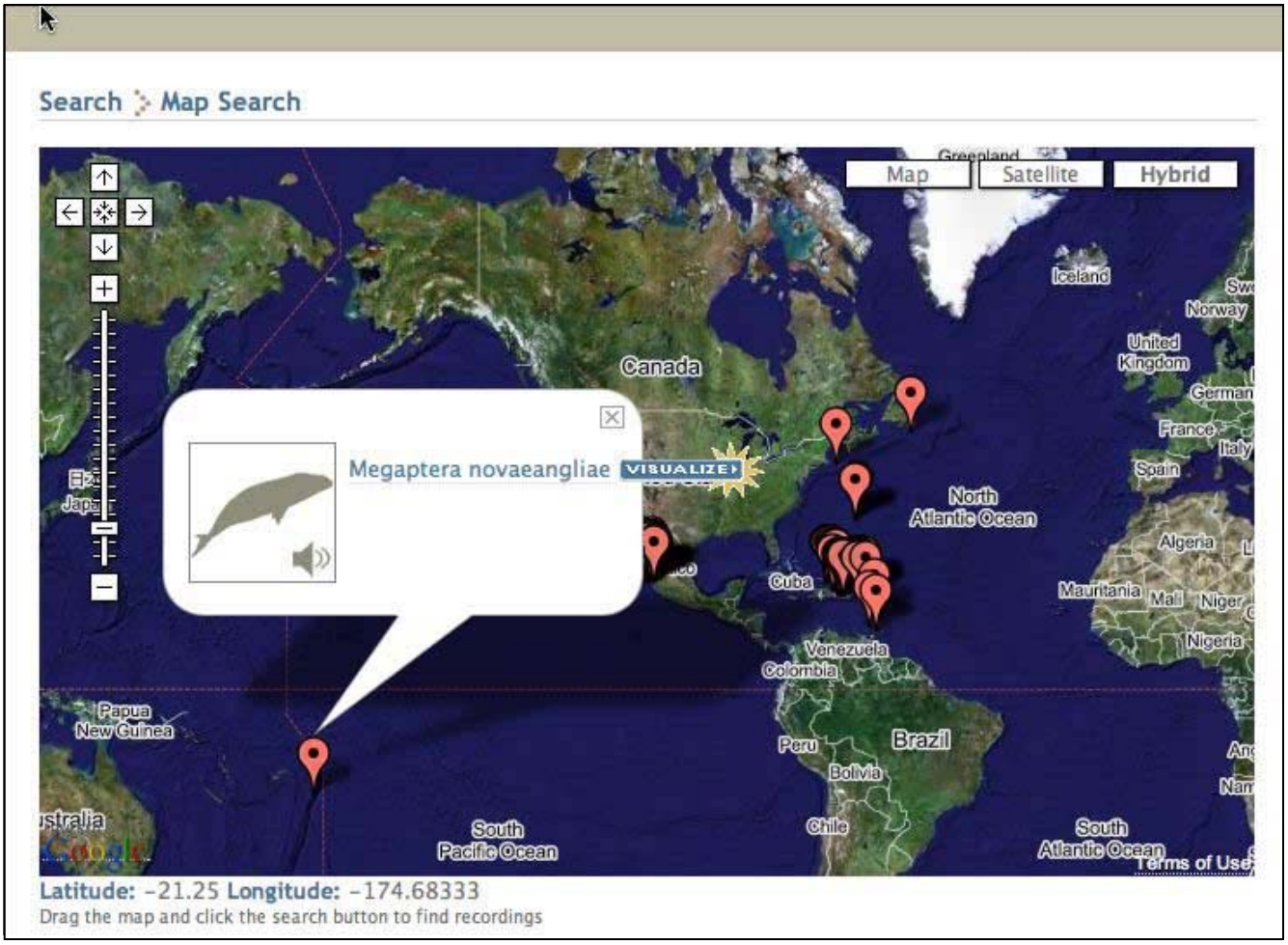

Figure 2: Google map display of locations of recordings and balloon giving more information and playback option for a selected site.

The user can then play a selected recording from either the map or search results and visualize the sounds as waveforms and/or spectrograms using a variety of customizable settings for bandwidth, time scale, frequency scale, color, and gridding. If the recording is a video, the player will also show the video synchronized with the sound and visualization displays. The player is based on Quicktime, which is free to all users and operates on both Windows and Macintosh platforms. The necessary plug-in is available on the Macaulay Library web site. Once installed, the user can use the player to play and visualize recordings found in a Macaulay Library search or recordings stored on their own computer. This allows users to compare a new recording of their own to reference recordings in the archive. Customized settings for spectrogram and waveform views can be stored on the user's computer to facilitate rapid standardization of the displays. The user can also identify specific sections within a recording at which they want playing to begin and end. The ability to insert these "mark in" and "mark out" points will also be used by annotators when the annotation tools are complete. A sample page from the player appears below:

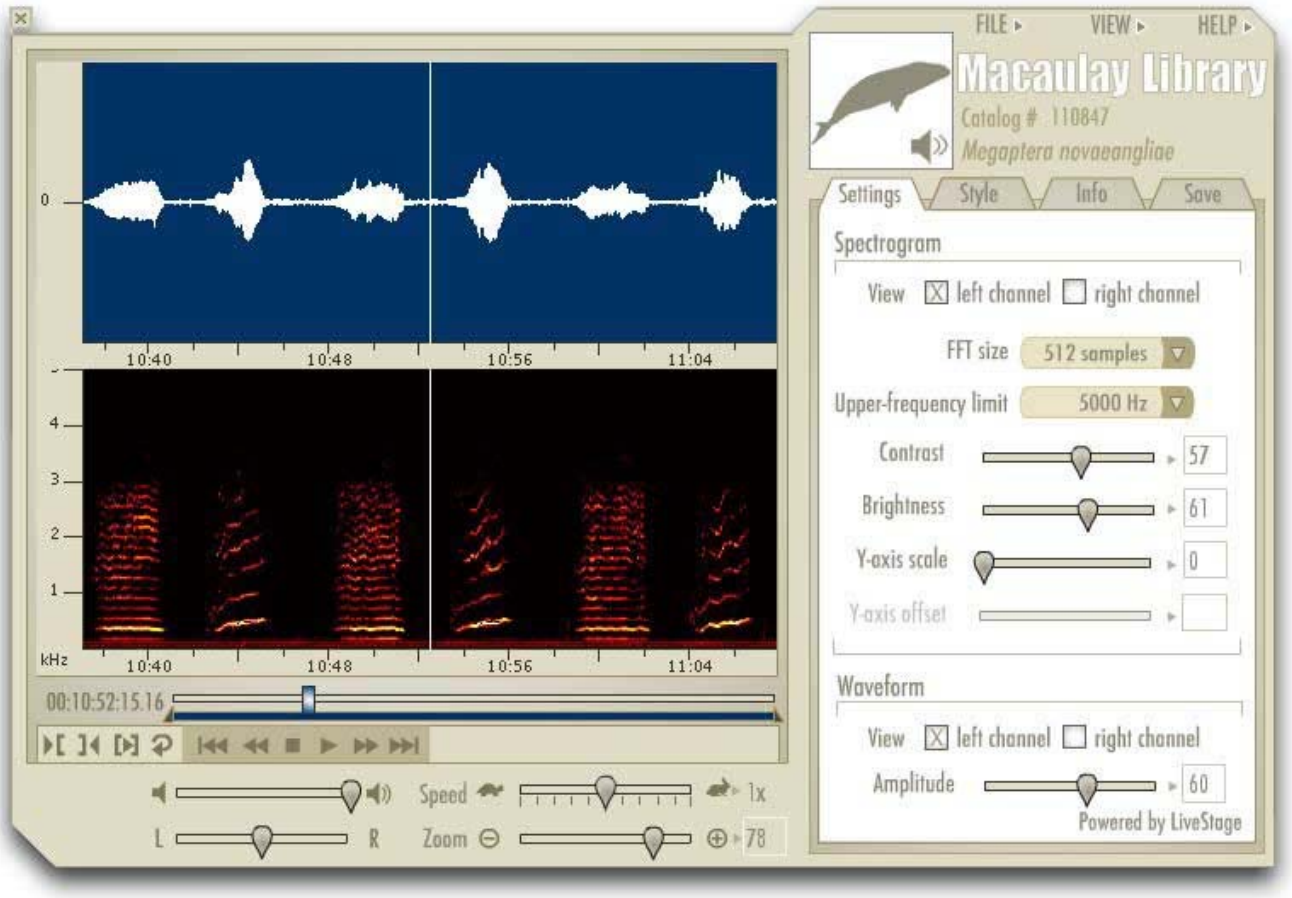

Figure 3: Sample page from free Macaulay Library player showing waveform, spectrogram, and control setting tabs for an audio recording of a humpback whale.

Selection of suitable feature measurements to be made automatically on all annotated segments of audio files is complete, and the relevant algorithms have been programmed into Matlab modules for distribution to participating laboratories for testing. Some substitutions or additions of features may occur based on feedback from the marine bioacoustics community.

RESULTS

Major results from this project to date include the creation of a proposed new metadata standard for the classification of animal behavior (http://ethodata.comm.nsdl.org/), an online tool produced in collaboration between the Cornell Lab of Ornithology and uBio (http://www.ubio.org/) for resolution of taxonomic synonymies, and the development of a browser-compatible platform-independent sound visualization tool that includes appropriate digital rights protections and the ability to identify segments within recordings for annotation and segment relocation and distribution.

IMPACT AND APPLICATIONS

National Security

While the U.S. Navy has its own archives of marine animal sounds that can be used to discriminate between man-made devices and animals, the growing Macaulay Library archive is becoming a broader

and more definitive source as it grows and users become more adept at exploiting the new tools to identify and retrieve specific sounds. The military will of course have full access to the entire collection.

Economic Development

Both commercial and public media frequently seek examples of sounds of newsworthy species from the Macaulay Library. The new tools developed here will make such requests much faster and effective as the media themselves will be able to search, audition, and select specific segments of audio and video recordings remotely on the web and download them for usage immediately.

Quality of Life

The general public is largely fascinated by marine mammals. Free access to our videos and audio recordings of these animals can enrich the lives of anyone with access to an online computer and browser.

Science Education and Communication

With support from NSF, the Macaulay Library is working with teachers to use its archives of animal behavior to enrich STEM education. The natural allure of marine animals provides a superb springboard to introduce students to many topics in biology and physics, as well as applied areas such as conservation and environmental change.

TRANSITIONS

Economic Development

The Macaulay Library is a major resource of sound and video recordings for public and commercial media, museums, zoos and aquaria, producers of products reproducing animal sounds, wildlife identification devices, CD and DVD nature productions, sound effects for the movie industry, etc.

Quality of Life

Macaulay Library provides sounds for web-based and kiosk public information sites, training tapes for bioacoustic censusing by wildlife biologists and conservation staff, workshops to train wildlife recordists and bioacoustic censusing staff, etc.

Science Education and Communication

Macaulay Library is one of the world's primary resources for archived sounds of animals and is thus widely used by scientists, teachers, and students. It is also an active member of the National Science Digital Library (NSDL) program and its collections are available through NSDL portals.

RELATED PROJECTS

Macaulay Library also has a concurrent grant from the NSF-funded National Science Digital Library program to maintain an NSDL portal and web pages that will maximize access and utilization of the animal sound and video collections for education at all levels. It has another (smaller) NSF grant to fund the development of an international metadata standard for the field of animal behavior. Finally, ONR is supporting generously the archival of the last half-century's accumulated field recordings of marine animals at the Macaulay Library. This has included funds for both equipment acquisition and staff salaries for archivists.